

THE PIONEER ANOMALY AND A MACHIAN UNIVERSE

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Abstract

We discuss astronomical and astrophysical evidence, which we relate to the principle of zero-total energy of the Universe, that imply several relations among the mass M , the radius R and the angular momentum L of a "large" sphere representing a Machian Universe. By calculating the angular speed, we find a peculiar centripetal acceleration for the Universe. This is an ubiquitous property that relates one observer to any observable. It turns out that this is exactly the anomalous acceleration observed on the Pioneers spaceships. We have thus, shown that this anomaly is to be considered a property of the Machian Universe. We discuss several possible arguments against our proposal.

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I. Introduction

In this paper, we discuss the so-called Pioneers' anomaly, which affects spaceships sent to the outskirts of the Solar system, consisting of a deceleration unaccounted by known physical causes.

We begin by describing Machian Universes, presenting this author's viewpoint, which consists in defining such Universes by the condition $E = 0$, i.e., the total energy is zero, and time-invariant. We also discuss some astrophysical similarities, to wit, the cosmological counterpart of Blackett's and Wesson's laws.

We end this paper with a discussion on previous referees' considerations.

II. What is meant by a Machian Universe?

Berman(2006b; 2007a; 2007b; 2007c), proposes that Mach's Principle, means a zero-total energy Universe. Berman(2006; 2006a), has shown this meaning of Mach's Principle without considering a rotating Universe. We now extend the model, in order to include the spin of the Universe, and we replace Brans-Dicke traditional relation, $\frac{GM}{c^2 R} \sim 1$, with two different relations, which we call the Brans-Dicke relations for gravitation, and for the spin of the Universe.

We shall consider a "large" sphere, with mass M , radius R , spin L .

We now calculate the total energy E of this distribution:

$$E = E_i + E_g + E_L, \quad (1)$$

where $E_i = Mc^2$, stands for the inertial (Special Relativistic) energy; $E_g \cong -\frac{GM^2}{R}$ (the Newtonian gravitational potential self-energy); $E_L \cong \frac{L^2}{MR^2}$ the Newtonian rotational energy. Other contributions to the total energy, might be added in relation (1), but we shall not do it here, for brevity.

If we impose that the total energy is equal to zero, i.e., $E = 0$ (Berman, 2006; 2006a; 2007a; 2007b; 2007c), we obtain from (1):

$$\frac{GM}{c^2 R} - \frac{L^2}{M^2 c^2 R^2} \cong 1 \quad . \quad (2)$$

As relation(2) above should be valid for the whole Universe, and not only for a specific instant of time, in the life of the Universe, and if this is not a coincidental relation, we can solve this equation by imposing that $\dot{E} = 0$ (i.e., the zero-total-energy is a time-invariant result), so that we are left with a single possible solution:

$$\frac{GM}{c^2 R} = \gamma_G \quad , \quad (3)$$

$$\frac{L}{McR} = \gamma_L \quad , \quad (4)$$

subject to the condition,

$$\gamma_G - \gamma_L^2 \cong 1 \quad , \quad (5)$$

where the $\gamma's$ are constants having a near unity value.

We now derive the following generalized Brans-Dicke relations, for gravitation and spin:

$$\frac{GM}{c^2 R} = \gamma_G \quad , \quad (3)$$

$$\frac{GL}{c^3 R^2} = \gamma_L \quad , \quad (6)$$

Instead of deriving the above Brans-Dicke relations, by means of the zero-total energy principle, coupled to the hypothesis that each term should be valid, not only for the present Universe but also along all the history, since Planck's Universe, other authors (Sabbata and Sivaram, 1994) derived the B.D. relation for spin, on a heuristic procedure, which consists on the simple hypothesis that L should obey a similar relation as M .

We notice that $R \propto M$, and $L \propto R^2$, in case γ_G and γ_L are really constants.

It must be remarked, that our proposed law (3), is a radical departure from the original Brans-Dicke (Brans and Dicke, 1961) relation, which was an approximate one, valid for the

present Universe, while our present exact hypotheses implies that $R \propto M$, and $L \propto R^2$, for the entire span of the Universe's history.

With the present hypothesis, one can show, that independently of the particular gravitational theory taken as valid, the energy density of the Universe obeys a R^{-2} dependence (see Berman, 2006; 2006a; Berman and Marinho, 2001). For instance, from the definition of the inertial or matter energy density,

$$\rho_i = \frac{M}{V} \quad , \quad (7)$$

while,

$$V = \alpha R^3 \quad , \quad (\alpha = \text{constant}) \quad (8)$$

where ρ_i and V stand for energy density and tridimensional volume, we find:

$$\rho_i = \left[\frac{\gamma_G}{G} \right] R^{-2} \quad . \quad (9)$$

If we apply the above relation, for Planck's and the present Universe, we find:

$$\frac{\rho_i}{\rho_{Pl}} = \left[\frac{R}{R_{Pl}} \right]^{-2} \quad . \quad (10)$$

If we substitute the known values for Planck's quantities, while we take for the present Universe, $R \cong 10^{28}$ cm, we find a reasonable result for the present energy density. This shows that our result (relation 9), has to be given credit.

III. Pioneers' anomaly and the spin of the Universe

It should be remembered that the origin of Planck's quantities, say, for length, time, density and mass, were obtained by means of dimensional combinations among the constants for macrophysics (G for gravitation and c for electromagnetism) and for Quantum Physics (Planck's constant $\frac{h}{2\pi}$). Analogously, if we would demand a dimensionally correct Planck's spin, obviously we would find,

$$L_{Pl} = \frac{h}{2\pi} \quad . \quad (11)$$

This is exactly what we would obtain from (6), when we plug R_{Pl} for R , and obtaining $L = L_{Pl}$.

From Brans-Dicke relation for spin, we now can obtain the present angular momentum of the Universe,

$$L = L_{Pl} \left[\frac{R}{R_{Pl}} \right]^2 \cong 10^{120} \left(\frac{h}{2\pi} \right) = 10^{93} \text{ g cm}^2 \text{ s}^{-1} \quad . \quad (12)$$

This estimate was also made by Sabbata and Sivaram(1994), based on heuristic considerations(see also Sabbata and Gasperini, 1979).

Sabbata and Gasperini(1979), have calculated the angular speed, for the present Universe. Though they mixed their heuristic calculations with some results obtained from Dirac's LNH (Large Number Hypothesis), including a time variation for the gravitational "constant", we now show that, if we take for granted that $G = \text{constant}$, and by means of the generalized Brans-Dicke relations we find, by considering a rigid rotating Universe, whereby:

$$L = MR^2\omega \quad , \quad (13)$$

so that,

$M\omega = \text{constant}$, (because $L \propto R^2$ as we have shown earlier), we shall have:

$$\omega_{Pl} = \frac{c}{R_{Pl}} = 2 \times 10^{43} \text{ s}^{-1} \quad , \quad (14)$$

and, for the present,

$$\omega = \frac{c}{R} \cong 3 \times 10^{-18} \text{ s}^{-1} \quad . \quad (15)$$

Sabbata and Gasperini(1979), pointed out that the same numerical angular speed is obtained for Gödel's Universe, and also for the Sun's peculiar velocity through the cosmic microwave background.

We remark that $\gamma_G \cong 2$ is to be exact and not approximate, if we consider the result by Adler et al (1975), for the energy of a spherical mass, obtained by means of pseudotensors.

The Pioneers' anomaly, is described by a centripetal acceleration of an up to now unexplained nature, which affects two spaceships launched on opposite directions, which are

by now in the outskirts of the Solar system (Anderson, 1999). Its value is $a' \cong -8 \times 10^{-8} \text{cm/sec}^2$.

For a Machian Universe, taken care of result (15), we can obtain the value for an ubiquitous centripetal acceleration,

$$a = -\omega^2 R \quad . \quad (16)$$

If $R \cong 10^{28} \text{cm}$, as is known for the causally related Universe, we find:

$$a = -9 \times 10^{-8} \text{cm/sec}^2 \cong a' \quad . \quad (17)$$

It is necessary to point out that, for a Machian Universe, we should have this extra acceleration, along the direction pointing from the observed to the observer. It affects any two pairs of, observer versus observed, points in space. The striking match between a and a' must point to a possible solution to the Pioneers' anomaly; the only necessary hypothesis is that the Universe is endowed with the Machian properties shown above.

IV. Astrophysical and Cosmological Laws

There are two astrophysical empirical laws, called after Blackett, and Wesson, relating, the first, spins and magnetic moments of astrophysical objects and stars; the second, relating spins and masses, of the same objects (Sabbata and Sivaram, 1994; Wesson, 2006).

If we call by U_a , the magnetic moment, it is found the approximate relation for astrophysical spins L_a ,

$$L_a = qU_a \quad (\quad q \approx 10^{15} \quad \text{g}^{1/2} \cdot \text{cm}^{-1/2} \quad) \quad ,$$

while,

$$L_a = pM_a^2 \quad (\quad p \approx 10^{-15} \quad \text{g}^{-1} \cdot \text{cm}^2 \text{sec}^{-1} \quad) \quad ,$$

where M_a represent the masses of the objects.

If we remember the Machian properties of Sections II and III, we find that the last relation is obeyed by the Machian Universe, with a not very smaller value for the constant p , say

$10^{-17} \text{ g}^{-1} \cdot \text{cm}^2 \text{sec}^{-1}$. The astrophysical law is verified for several different objects; the Universe, obeys such law, at any instant, and we guess that the astrophysical value of p , will approach the Universe's one, as much as the observed objects have larger masses.

As to Blackett's law, we find that the Machian Universe should also obey it, with a not too much different numerical value for the constant q , and we also guess that the larger the mass of the objects, the more, the numerical values of the objects p will approach the one for the Universe.

It must be remembered, that the magnetic field of the Universe must obey the same R^{-2} – dependence for its energy density, i.e.,

$$\frac{B^2}{8\pi} \propto R^{-2} \quad .$$

We shall also need to add one more term in equation (1), in order to represent the magnetic field's energy contribution,

$$E_B = \frac{B^2}{8\pi} \cdot \frac{4\pi R^3}{3} \quad .$$

From experimental arguments, we fix the present value for B to be of order 10^{-6} Gauss.

Hence, the approximate numerical value for the Machian's q .

V. Pros and Cons of our Machian picture

We may argue that (1) it would be unclear who should measure the energy of the Universe, from the "outside"; (2) it would be unclear whether we may use Newtonian expressions for the calculations; (3) it would be mathematically impossible to derive several generalized Brans-Dicke equalities, from a single equation describing the energy E ; (4) the local energy-momentum conservation, described by the covariant divergence of the energy-momentum tensor, would be no more valid, and therefore, the model is inconsistent; (5) the large angular-momentum of the Universe, is not astronomically confirmed; (6) this paper does not obey any viable theory of Gravity, and it does not supply new results about the Universe; (7) the Brans-Dicke relation is numerically verified for the present Universe, but the generalized

counterpart, which is an equality, is obviously also verified, so that, nothing new has been provided, and, the coincidence has a lot of uncertainty; (8) what Berman is doing, is just an exercise in dimensional analysis, like has been earlier done for instance, by Dirac and Eddington; (9) this theory is heuristic, and, thus, not necessarily scientific.

However, we answer those "cons", with the following "pros": (A) allegations about the energy of the Universe, and, precisely, about its zero-value, can be traced to Feynman (Feynman, 1962-3), Rosen (Rosen, 1994-95), Cooperstock and Israelit (1995), Hawking (2001) and many others. Berman has derived this from Robertson-Walker's metric, so that it is a valid result in Relativistic Cosmology, for any tri-curvature value (Berman, 2006, 2006a). The existence of a "spectator" is a philosophical question, rather than a scientific one; (B) Machian properties have been proposed in different gravity theories, so there is no one single theory that owns such attributes (remember the origin of Brans-Dicke theory); (C) the several generalized Brans-Dicke equalities, derived from the energy equation, are just, the most simple set of solutions for the $E = 0$ equation; (D) the mentioned solutions, have very interesting properties: for instance, the relative contributions of each type of energy towards the total amount, is time-independent. This fact is coherent with the recently proclaimed and experimentally observed result that the Universe has been Λ -dominated since long ago; (E) we never told that "Machian" conditions only can mean "general relativistic" ones; (F) you can not blame our paper for the fact that the angular momentum is high for the present Universe, because we have derived a correct result, i.e., the small amount of angular velocity in the present Universe, which angular velocity is undetectable with present technological tools; (G) our framework is relativistic, in the low Newtonian limit, but this could be called, also, a Sciama gravitational theory (Sciama, 1953); (H) we can extend all forms of energy densities towards Planck's time, by going back from the present: no inconsistency with Planck's energy density would be found. It must be not overlooked that the effective energy density of the Universe is zero-valued, corresponding to a zero-total energy. This is attained by subtracting, from all kinds of energy densities (corresponding to inertial mass, spin, cosmological constant, radiation, etc.), which are positive, the energy density due to the self-gravitational term, which is negative, and balances the first ones.

We refer to the extremely important books by Sabbata and Sivaram(1994) and Wesson(2006), where there are clues about the rotation of the Universe, for instance, through

Blackett and Wesson's formulae, which relates spin and magnetic field.

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